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Expert System for Biddability, Constructibility, and Operability Review

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# **Concept Development of an Automated Construction Design Review Advisor**

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This report presents the interim results of research to develop a personal computer-based hypertext system to help U.S. Army Corps of Engineers (USACE) personnel perform constructibility reviews on construction design documents. It identifies the most promising sources of constructibility review information, presents formulation of a concept prototype as well as review comments obtained after a demonstration to USACE Omaha District field design reviewers, and identifies future efforts required to develop a fully operational system.

The BCO ADVISOR represents the second step in design review. The Automated Review Management System (ARMS) improved the management of design review. The BCO ADVISOR will improve the performance of design review.

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## FOREWORD

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## CONTENTS

	Page
SF 298	1
FOREWORD	2
LIST OF TABLES AND FIGURES	4
<b>1 INTRODUCTION .....</b>	<b>7</b>
Background	
Objective	
Approach	
Mode of Technology Transfer	
<b>2 CONCEPT DEVELOPMENT .....</b>	<b>8</b>
Need for Constructibility Review	
Current Constructibility Reviews	
<b>3 SOURCES OF CONSTRUCTIBILITY REVIEW INFORMATION .....</b>	<b>10</b>
Military Design Review Course	
Automated Systems/Databases	
Sample Projects	
District and Division Checklists/Manuals/Guides	
Other Sources	
<b>4 DESIGN PHILOSOPHY FOR THE BCO ADVISOR .....</b>	<b>15</b>
Selection of Software	
Original BCO ADVISOR Format	
Field Discussions and Comments	
Review Workshop	
Current BCO ADVISOR Format	
<b>5 PROGRAM DESCRIPTION .....</b>	<b>18</b>
Hardware Requirements	
User Interface Features	
Program Features	
<b>6 INTERIM CONCLUSIONS AND CURRENT EFFORTS .....</b>	<b>30</b>
APPENDIX A: Division and District Checklists/Manuals/Guides	31
APPENDIX B: Industry and Academic Sources	32
APPENDIX C: Redicheck System Sample Checklist	33
APPENDIX D: Basic BCO ADVISOR Logic Trees	34
<b>DISTRIBUTION</b>	

## **TABLES AND FIGURES**

<b>Tables</b>		<b>Page</b>
1	Distribution of CERS Comments by Specification Section	13
2	Distribution of CERS Comments by Comment Type	14

<b>Figures</b>		<b>Page</b>
1	Cost Savings of Constructibility Review	8
2	Automated Review Management System (ARMS)	11
3	BCO ADVISOR Format	17
4	Program Structure	17
5	Knowledge Base Selection	20
6	Opening Comments Screen	20
7	Hypertext demonstration for "biddability"	21
8	Output File Naming Prompt	21
9	Help Text	22
10	Filing Options	22
11	Project Data Entry	23
12	Review Selection	23
13	Discipline Selection	24
14	Division Selection	24
15	The Print All Checklists Option	25
16	Broadscope Selection Screen	25
17	Broadscope Breakdown	26
18	Discipline Cross-Referencing	26

<b>Figures</b>		<b>Page</b>
19	Checklist of Review Guidelines	27
20	Exporting Comments	27
21	Text File Name Screen	28
22	Exiting the Checklist Function	28
23	Printing an Output File	29
24	Final Reference Screen (With Point-of-Contact Information)	29
25	Improvement of Design Review	30
D1	Overall Review Tree	34
D2	35 Percent Concept Review Tree	34
D3	95 Percent Final Review Tree	35
D4	Special Issues Review Tree	35

# CONCEPT DEVELOPMENT OF AN AUTOMATED CONSTRUCTION DESIGN REVIEW ADVISOR

## 1 INTRODUCTION

### Background

Errors, omissions, and inconsistencies in construction documents cause higher costs, delays, and time growth in U.S. Army Corps of Engineers (USACE) construction projects. To combat preconstruction errors, USACE has instituted a comprehensive design review program which includes an in-house technical review, an end-user functional review, a post-engineer operational/maintainability review, and a field engineer constructibility review. Improvements in the review process have potential for significant cost savings. The Construction Industry Institute (CII) suggests that saving 6 to 23 percent of an original estimate is achievable through proper constructibility review.<sup>1</sup> This source and others cite on the order of at least a 10 to 1 payback from a constructibility review program.<sup>2</sup>

### Objective

The overall objective of this research is to develop a robust, easy-to-use personal computer (PC)-based expert system to assist in conducting constructibility reviews. As a PC-resident program, the Biddability, Constructibility, Operability (BCO) ADVISOR will provide guidance on what constitutes a BCO review as well as suggestions on procedures to follow should errors be found. This report describes the formulation of a concept prototype.

### Approach

Existing sources of constructibility review guidelines were identified and appropriate information was excerpted. A prototype BCO ADVISOR was then developed and demonstrated to field operating activity (FOA) reviewers. Their comments were integrated into a revised prototype which was demonstrated to selected FOA representatives at a USACERL-hosted workshop. After the workshop comments on the system concept were incorporated, a comprehensive effort has been made to acquire and incorporate information into BCO ADVISOR. Extensive field testing will occur before the system is completed.

### Mode of Technology Transfer

A prototype system will be field tested and modified as necessary before a final, fully documented software product is available for Corps-wide distribution. At this time, it is anticipated that the Directorate of Military Programs Construction Division will initiate an authorizing document in the form of a policy letter, and will authorize distribution of the system for use by Corps FOAs. Maintenance will be accomplished by each FOA or by an independent contractor yet to be identified.

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<sup>1</sup>Constructibility: A Primer, Publication 3-1 (Construction Industry Institute [CII], July 1986), pp 1-11.

<sup>2</sup>William T. Nigro, "Redicheck," *Military Engineer*, No. 489 (Sept - Oct 1983), p 420.



## 2 CONCEPT DEVELOPMENT

### Need for Constructibility Review

Constructibility review is defined by Engineer Regulation (ER) 415-1-11 as "the compatibility of the design with the site, materials, methods, techniques, schedules, and field conditions."<sup>3</sup> Constructibility includes ease of construction, enhancement of contractor productivity, adaptation of the designs to site conditions and restrictions, and tradeoffs between custom and standard components.

The maximum cost savings from constructibility reviews occur early in the design process when gross errors related to site conditions and facility components should be resolved. Typically, these issues should be identified during the USACE 35 percent Concept Design Constructibility Review. At Final Design Constructibility Review, architect/engineers (A/E) are reluctant to implement significant or radical design changes. This relationship is illustrated in Figure 1.

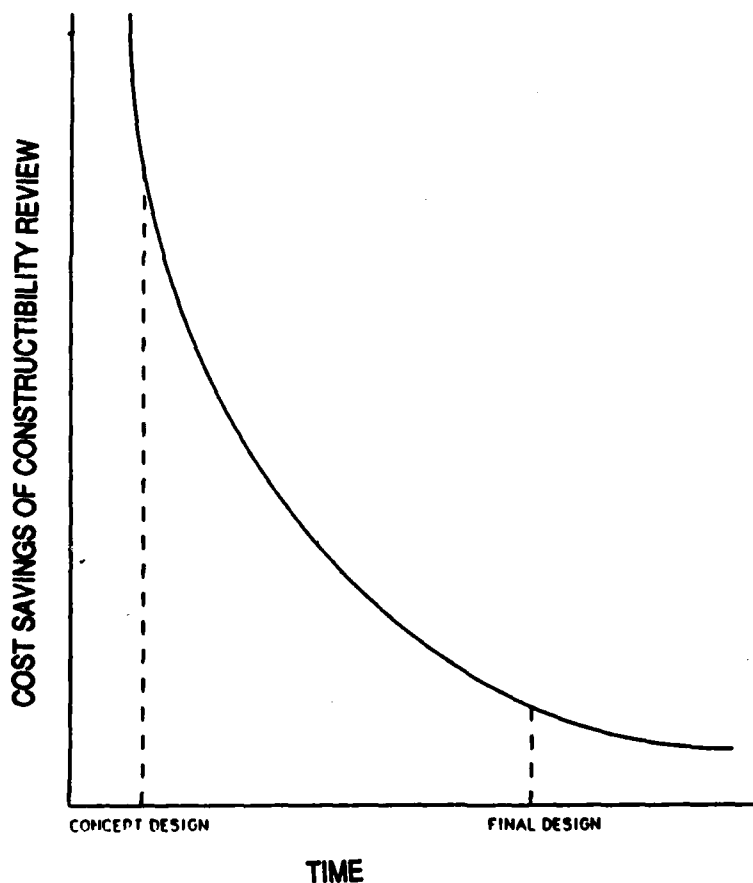


Figure 1. Cost savings of constructibility review.

<sup>3</sup> Engineer Regulation (ER) 415-1-11, *Constructibility, Biddability, and Operability* (Headquarters, Department of the Army [HQDA], 1988), p. 1.

## Current Constructibility Reviews

Currently, USACE requires two constructibility reviews for each military project: one at concept (35 percent) and the second at final design (95 percent). Studies by the U.S. Army Construction Engineering Research Laboratory (USACERL)<sup>4</sup> and Mogren<sup>5</sup> both identified three major causes of contract modifications: (1) design deficiencies, (2) user-requested changes, and (3) unknown site conditions. Since field construction offices do not participate in all design reviews, constructibility input is not always assured. The USACERL study determined that, although 56 percent of all construction contract modifications are to correct design deficiencies, limited manpower restricted full realization of benefits of constructibility reviews.

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<sup>4</sup> J.G. Kirby, R.P. Cannalte, D.K. Hicks, and E.J. Japel, *Constructibility and Design Reviews: Analysis and Recommendations for Improvement*, Technical Report (TR) P-89/15/ADA212602 (U.S. Army Construction Engineering Research Laboratory [USACERL], September 1989).

<sup>5</sup> Eric T. Mogren, *The Causes and Costs of Modifications to Military Construction Contracts* (U.S. Army Command and General Staff College, Fort Leavenworth, KS, 1986).

### 3 SOURCES OF CONSTRUCTIBILITY REVIEW INFORMATION

The following sources of information were examined to determine if they contained constructibility review topics that could be incorporated in BCO ADVISOR.

#### **Military Design Review Course**

The USACE Training Management Division at Huntsville holds 3-day Military Design Review courses to train architects, engineers, technicians, and project managers to understand why, what, and how reviews are conducted. The 22-hour course covers policies, principles, procedures, and techniques used in design reviews. The training includes workshops that provide hands-on practice, feedback, and discussion.

The course explains typical approaches, methodologies, and techniques used in performing reviews, and the accompanying manual includes checklists for various disciplines. The course includes several design issues that could be included in the BCO ADVISOR.

#### **Automated Systems/Databases**

##### *Automated Review Management System (ARMS)*

ARMS was developed by USACERL to help USACE project managers track and manage constructibility and design reviews of construction projects. ARMS manages review deadlines at all user levels, provides database management for comment manipulation and analysis, provides for electronic forwarding of comments, and permits on-line or off-line batch comment generation and uploading using standard word processors. Figure 2 illustrates how ARMS controls the flow of information during the review process.

Since ARMS is a management tool it can provide review comments from previous projects, which can reveal issues of concern to review managers, and possibly the methodology used.

##### *Construction Appropriations Programming, Control, and Execution System (CAPCES)*

CAPCES enables users to manage and track approximately 16,000 individual projects in the Army construction program through planning, budgeting, and execution. It provides project and program status reports to Congress, the Office of Management and Budget (OMB), the Office of the Secretary of Defense (OSD), the Department of the Army (DA), Major Army Commands (MACOMs), and USACE activities. It is interactively updated by several divisions of Headquarters, USACE (HQUSACE) and the Directorate of Military Programs.

Because CAPCES provides project and appropriation-level fiscal controls and records for the Military Construction, Army (MCA) program, information in the system is not geared for field operations such as constructibility reviews. Although it manages and assembles the efforts of many installations, USACE districts and divisions, and Headquarters offices, the data it supplies are more useful for systems other than the BCO ADVISOR.

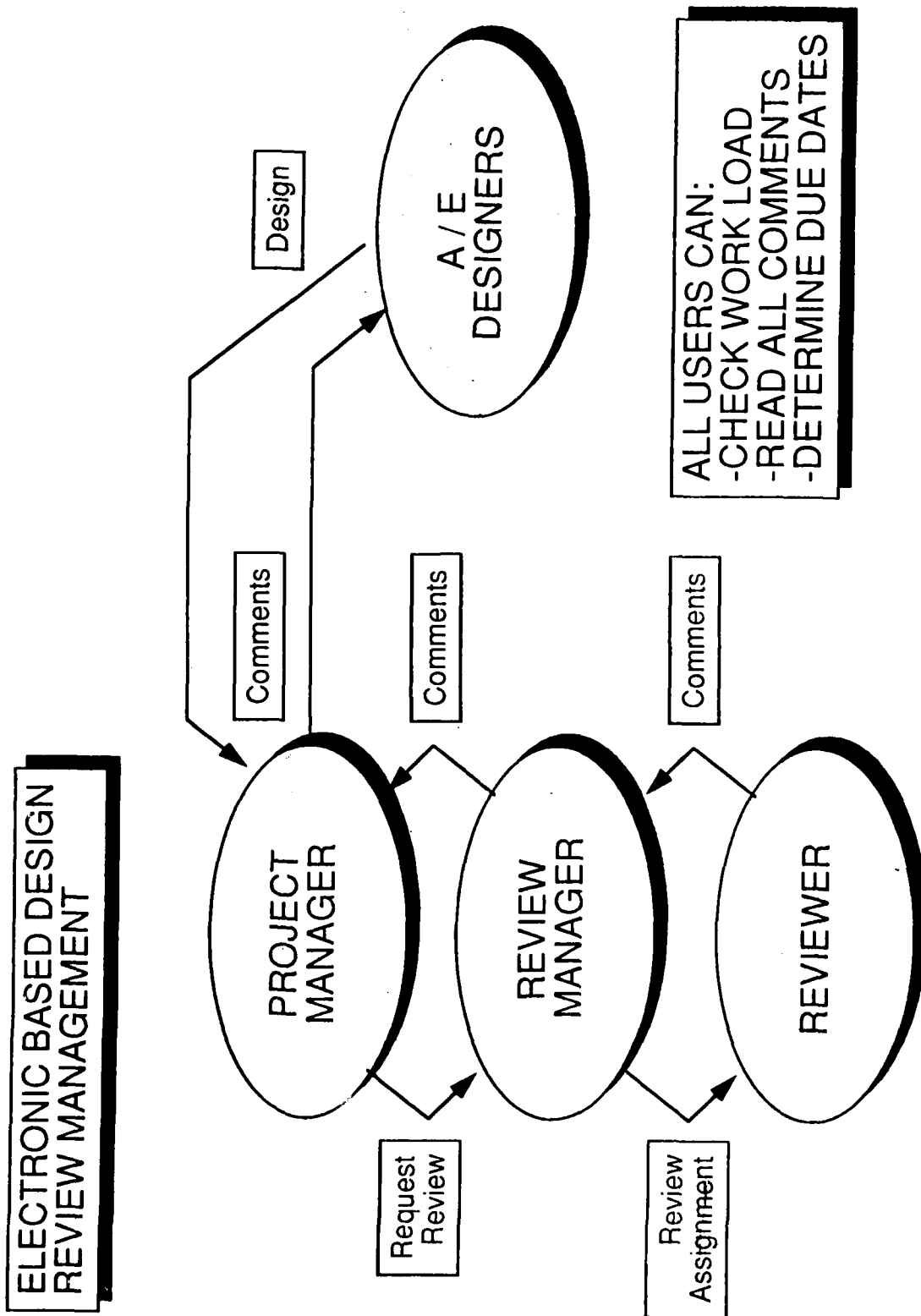


Figure 2. Automated Review Management System (ARMS).

### *Construction Evaluation Retrieval System (CERS)*

CERS is a computer database that stores information from Design/Construction Evaluation (DCE) and warranty inspections conducted since 1979. The information consists of general deficiencies, comments, and commendations for various features of work reviewed by DCE teams. The data can be sorted using different options, such as the type of comment, Construction Specification Institute (CSI) code, facility category code, or installation/location. As of April 1989 there were close to 2600 entries in the system. Distribution of comments in the specifications section and by comment type are illustrated in Tables 1 and 2.

The CERS database focuses on construction deficiencies, although it includes some comments on design and BCO factors. Much information is available but retrieval is cumbersome. Nevertheless, the deficiencies listed in the system often have BCO implications. Preliminary work with CERS has provided checklist items that can be used in the constructibility review system. Further study as the database is updated may yield more review issues.

### *Construction Grants Program (CGP) Lessons Learned System*

The CGP Lessons Learned System<sup>6</sup> was created to identify problems in the Construction Grants Program and collect and disseminate ideas on solutions to them. The vehicle used is the Grant Observation, which describes situations and possible actions. An "observation" may be a problem discovered in an inspection; may concern contractors, materials, suppliers, or vendors; may be administrative in nature; or may be a potential problem that was creatively averted.

Comments in Lessons Learned tend to involve administrative rather than construction problems. Grant Observations can be screened for design- and BCO-related comments, but only a few of these can be expected.

### **Sample Projects**

As in the case of ARMS, sample projects with reviewer comments can be a source of constructibility checklist items. Redlined drawings and specifications from various stages of project completion (35 percent Concept Review, 65 percent Intermediate Review, 95 percent Final Review, etc.) are available from district and division offices. Representing projects from different construction categories, these documents may reveal frequent BCO deficiencies that can be used in checklists for the expert system.

### **District and Division Checklists/Manuals/Guides**

In line with ER 415-1-11, district and division offices have developed review guides and BCO checklists for conducting constructibility reviews. Checklists are also available from design manuals and A/E guides, although these documents concentrate more on design rather than on constructibility issues.

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<sup>6</sup>*Lessons Learned System: Lessons Learned From the EPA-CGP Grant Administration and Construction Process (User's Manual)* (U.S. Army Corps of Engineers, St. Paul District, 1988).

**Table 1**  
**Distribution of CERS Comments by Specification Section**

Spec Division	Description	Number of Comments	Percent of Total
15000	Mechanical	764	29.50%
16000	Electrical	621	23.98%
0 to 900	Bidding Requirements	223	8.61%
	Others	147	5.68%
01000	General Requirements	122	4.71%
04000	Masonry	110	4.25%
08000	Doors and Windows	99	3.82%
05000	Metals	92	3.55%
03000	Concrete	84	3.24%
07000	Thermal and Moisture	83	3.20%
02000	Sitework	79	3.05%
09000	Finishes	66	2.55%
06000	Wood and Plastics	26	1.00%
10000	Specialties	24	0.93%
11000	Equipment	20	0.77%
13000	Special Construction	15	0.58%
14000	Conveying Systems	10	0.39%
12000	Furnishings	5	0.19%
		<u>2590</u>	<u>100.00%</u>

A number of potential review guidelines have been gathered from district and division checklists, manuals, and guides. A list of these guides is found in Appendix A.

#### **Other Sources**

##### *Engineer Pamphlet (EP) 420-1-1: Biddability, Constructibility, and Operability*

This pamphlet provides guidance on procedures for executing and managing BCO reviews of USACE designs. The appendices contain both a Detailed Plan Review Checklist and a Special Provisions Checklist that can be readily included in the constructibility expert system.

##### *Industry and Academic Sources*

A number of research papers on constructibility discuss the methodology of reviews and current practices relating to BCO in both the government and private sectors. A few of these sources provide checklists while others emphasize review techniques and the benefits of incorporating constructibility into the design and construction process. A list of sources examined is found in Appendix B.

##### *Redicheck*

Redicheck is a structured review process of procedural instructions and a checklist that addresses the source of most design errors and omissions—the point of interface between disciplines. It provides

**Table 2**  
**Distribution of CERS Comments by Comment Type**

Comment Code	Description	Number of Comments	Percentage of Total
CR	Const.-Routine Design/Const. Eval.	1396	53.90%
DR	Design-RDCE	753	29.07%
OR	Other-RDCE	254	9.81%
DP	Design-Post Completion Inspection	105	4.05%
	NON-STANDARD CODES	33	1.27%
DF	Design-Design Criteria Feedback	20	0.77%
CP	Const.-PCI	13	0.50%
OP	Other-PCI	5	0.19%
DW	Design-Warranty Inspection	5	0.19%
CF	Const.-DCF	2	0.08%
OF	Other-DCF	2	0.08%
MP	Maintenance-PCI	1	0.04%
CW	Const.-WI	1	0.04%
CE	Const.-Facility Engr. Contract	0	0.00%
ME	Maintenance-FEC	0	0.00%
DE	Design-FEC	0	0.00%
OE	Other-FEC	0	0.00%
MF	Maintenance-DCF	0	0.00%
MR	Maintenance-RDCE	0	0.00%
MW	Maintenance-WI	0	0.00%
RC	Other-WI	0	0.00%
		2590	100.00%

a logical, orderly approach to checking construction drawings and specifications by examining areas where disciplines interrelate or occur in different specialties. The U.S. Navy first used Redicheck in 1982 at the construction office at Trident Naval Submarine Base, Kings Bay, GA. Since then, the office has reduced construction change orders with a corresponding cost decrease.

The complete Redicheck Plan and Specification Review includes the following sections: (1) Preliminary Review, (2) Specification Check, (3) Plan Check Civil, (4) Plan Check Structural, (5) Plan Check Architectural, (6) Plan Check Mechanical and Plumbing, (7) Plan Check Electrical, (8) Plan Check Kitchen/Dietary. Each section contains a list of items to verify to eliminate inconsistencies among documents. An examination of Redicheck-found errors indicated the system had a 10-to-1 payoff rate.

Redicheck is applicable to constructibility because the checklist pinpoints where interdisciplinary coordination errors often occur in BCO reviews. The checklist items can be readily integrated into the constructibility expert system, but Redicheck will not eliminate other reviews that should occur on most projects. Redicheck is most suited for multidisciplinary vertical construction projects and may not apply to all construction categories. However, the data are a good starting point for reviewing plans and specifications. Appendix C shows an example of a checklist from the system.

## **4 DESIGN PHILOSOPHY FOR THE BCO ADVISOR**

Assuring that a constructibility review has been completed may be a problem for reviewers who have little or no BCO background or who tend to concentrate on their area of expertise. To ensure that a review covers all topic areas, a guide is necessary to direct reviewers through the complete review.

### **Selection of Software**

The design review process is difficult to formalize. Checklists tried by various districts have had a fundamental conflict: ease of use versus robustness. An easy-to-use checklist is short, simple, and requires little time to use. Therefore, it cannot be very detailed or provide much information. A robust checklist, however, can be very comprehensive and cover numerous items, but this makes it difficult and time consuming to use effectively. The goal of this research is to develop a design review support system that is both robust and easy to use.

Expert systems and hypertext are two recently developed types of computer programs appropriate for this effort. Expert systems reach conclusions by matching rules against facts obtained from the system user. Typically they can explain how the conclusion was reached. Since design review rules cannot be easily defined, the development of a traditional expert system for design review seemed unlikely. Hypertext uses an associative (relational) linkage of information instead of a serial (sequential) relationship, allowing the user to branch to different texts that fully define an issue. Hypertext can be viewed as a series of nested reference sources. For example, examining roof details could lead to information about snow loads, then branch to allowable roof slopes categorized by geographical region, then on to allowable roofing materials. This information also could be gathered through direct guidance.

A recently available expert system shell called KnowledgePro successfully combined expert systems with hypertext. This program was selected for the BCO ADVISOR since it allows design review text interrelationships and controls the level and direction of the information presented. Thus the BCO ADVISOR can present various levels of support without excessive or unwanted detail.

### **Original BCO ADVISOR Format**

To provide full review guidance, the format for the BCO ADVISOR initially divided the review process into two general types as required by Corps regulations: a 35 percent Concept Review and a 95 percent Final Review. The first prototype used a series of menus for selecting the type of review, the class of facility being reviewed, and a particular aspect of constructibility (e.g., drawings, specifications, site or building design, contract provisions, construction conditions). Subsequent menus narrowed the review until an appropriate checklist of review guidelines was displayed.

### **Field Discussions and Comments**

The original prototype was demonstrated to engineers in the Constructibility Review Section at Omaha District, and comments were generated during field discussions. One important suggestion made during the demonstration was to include some special topics unfamiliar to most reviewers. Consequently, a Special Issues Review was incorporated into the system to complement the Concept Review and Final Review. Another significant recommendation was to make the system more usable for experienced



reviewers who have already established their own techniques for checking and evaluation. Experienced reviewers need guidance on unique issues and a method of investigating whether identified BCO deficiencies imply additional deficiencies in other areas. These and other comments led to additional menu items, modified display formats, and revised terminology in the program.

## **Review Workshop**

To ensure that the design was both comprehensive and responsive to user needs, a review workshop was organized and held at USACERL. Corps personnel involved in constructibility reviews were given a briefing on the project approach and system design. Following a demonstration of the BCO ADVISOR they were allowed to give an in-depth commentary on the program structure and user interface. Several suggestions were made about the domain for BCO reviews, the program structure, additional topics for review, the classification of review information, and input/output capabilities. Other sources of constructibility knowledge were also identified, and plans were made for a follow-up workshop and limited distribution of a revised system reflecting this input.

## **Current BCO ADVISOR Format**

The current program format still classifies review topics according to the type of review being conducted (i.e., 35 percent Concept Review or 95 percent Final Review) along with a Special Issues Review category. The 35 percent and 95 percent review categories are divided into 7 basic design disciplines. The disciplines under 95 percent are split into their applicable CSI divisions due to the availability of more detailed design information. Each discipline (35 percent) or CSI Division (95 percent) contains its own set of review guidelines to which the reviewer refers while checking the contract documents. Figure 3 illustrates the fundamental system format. *This breakdown reflects the manner in which construction drawings are normally arranged and distributed to various reviewers.* It also allows for the concurrent review of drawings and specifications—the typical and most comprehensive approach to reviewing drawings and specifications for a particular project. Only the Special Issues Review uses its own unique classification of review topics. These topics are usually very project-specific and are most likely to be customized to the differing needs of Districts and Divisions. They are provided for experienced reviewers who do not have to be "led by hand" through either the Concept or Final Review but require information on review issues encountered only once in a while. This type of review is also meant to encompass issues applicable to the more atypical facility classes listed in AR 415-28 (*DA Facility Classes and Construction Codes*). The logic trees in Appendix D present the various review topics as they are presently classified in the program.

The essential parts of the program consist of instructions to read the checklists from external text files that are separate from the program code itself. One advantage of this type of system design over others is that the program code is shorter and easier to debug. A greater advantage is that the reviewers can customize the checklists to fit their needs without having to work through the program code itself.

A typical review session would have the reviewer requesting guidelines within a particular topic area from a series of menus. The guidelines provided by the program would then be used as a basis for checking for deficiencies in the contract documents. The complete review would involve examining the documents following the guidelines listed under the applicable topics of the BCO ADVISOR. Within every checklist the reviewer has the option to export any relevant guidelines to an output file and to edit those guidelines into specific review comments pertaining to the project being reviewed. At the end of the session, a copy of the review comments can be printed for reference. When more than one session is needed to completely review a set of documents, the same output file can be used; additional comments can simply be appended to the file. Figure 4 illustrates the program structure of the BCO ADVISOR.

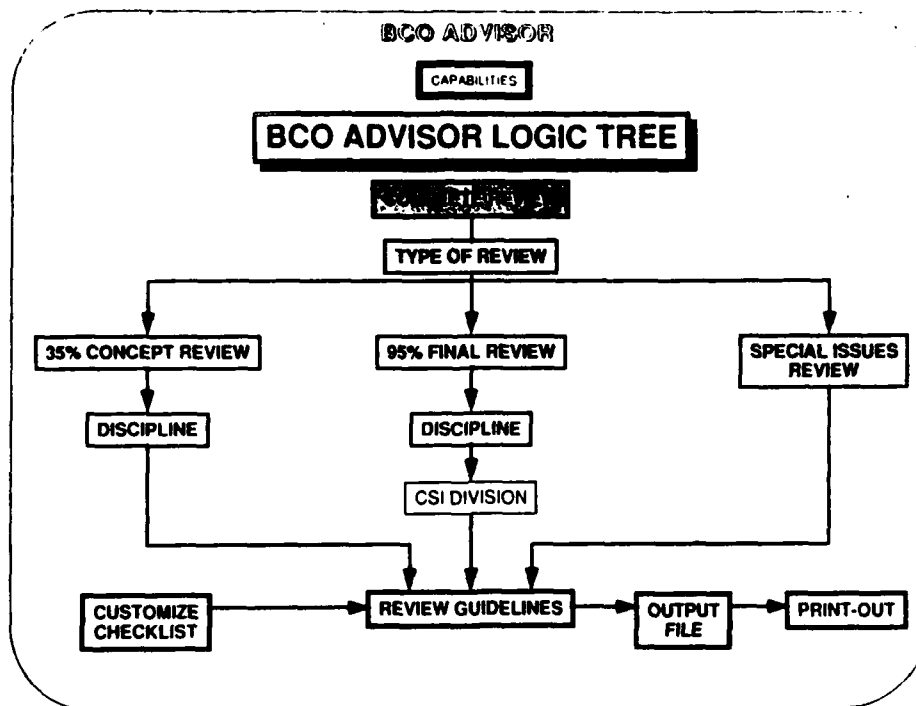


Figure 3. BCO ADVISOR format.

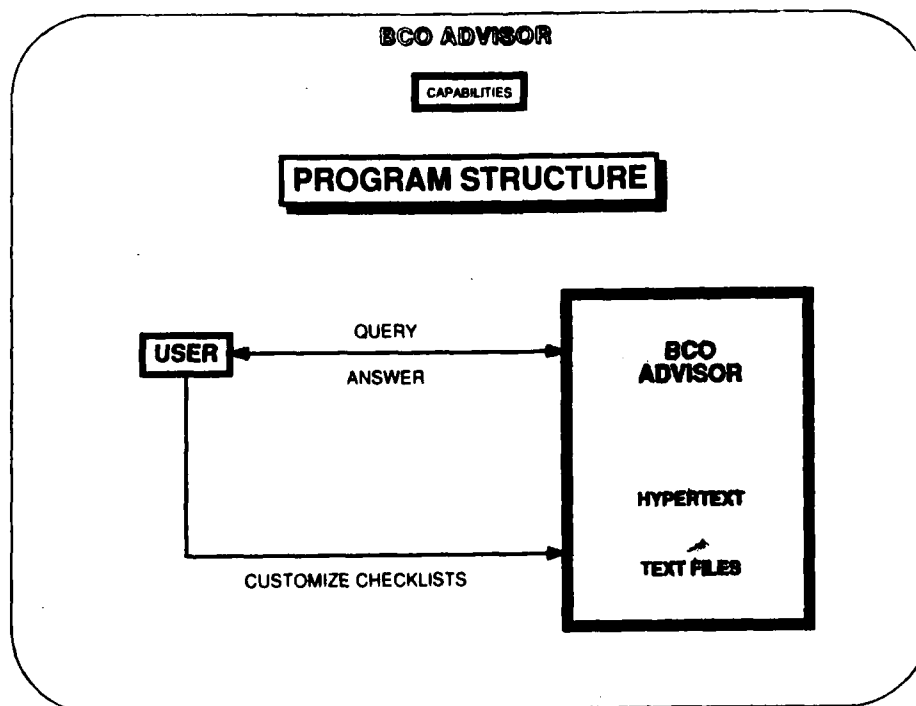


Figure 4. Program structure.

## 5 PROGRAM DESCRIPTION

### Hardware Requirements

The BCO ADVISOR runs on IBM PC, XT, AT, and PS2 compatible computers with at least 640K of random access memory (RAM). Although it can operate from diskettes, it is easier to use from a hard disk. The program is distributed on diskettes, and includes a runtime version of KnowledgePro, the compiled code of the BCO ADVISOR, and all necessary knowledge bases, text files, and program utilities.

### User Interface Features

The KnowledgePro interface uses either a keyboard or a compatible mouse. Keyboard input can be in the form of: (1) pop-up menus from which an item is selected by the user, (2) prompts after which an answer should be typed, and (3) editor windows that appear if an expected response from the user is longer than one line.

If a mouse is used, the cursor appears on the screen as a solid square. The left mouse button acts like an Enter key; and the right button like an Insert key to select or deselect items from a menu.

Function keys available for use are listed in the lower menu area of the screen. The cursor is moved with the arrow keys or by typing the first letter of the desired menu item and pressing Enter.

### Program Features

The BCO ADVISOR uses a menu-driven knowledge base program as the shell for the interactive checklists. The first menu (Figure 5),\* which is viewed after starting the program, asks which knowledge base is to be used. Selection of "ADVISOR" brings up the next screen (Figure 6), which is a brief summary of the program and basic instructions on the use of hypertext. Hypertext allows the user to obtain additional information on highlighted text by selecting a hypertext topic with the F3 key and using F4 to select and view the information. Figure 7 demonstrates the use of hypertext with respect to the word "Biddability" from the top of the previous menu. Pressing the space bar cancels the hypertext display and pressing it again moves the program to the next menu.

The task of this program is to create a printed checklist that will be sent to the designers for correction and incorporation of comments from the reviewer. These comments are stored in a file until the end of the program, when they may be printed. The name of this file can be changed by the reviewer (Figure 8), or the default setting "OUTPUT.FIL" can be accepted.

Throughout the program, help can be obtained by pressing the F1 key. This produces a short "help" message (Figure 9) that applies to the area of the program in use at the time. Pressing the space bar resumes normal operation when the user wishes to proceed.

If the file previously chosen for output is already in use, options are given on what to do with the new information that will be collected during the review process (Figure 10). If this is a new file the reviewer is asked to enter project data, which will appear at the top of the output document (Figure 11).

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\*Figures 5 through 24 are at the end of Chapter 5.

The next menu (Figure 12) presents the selections for the review being performed. If, for example, the "95% Final Review" is chosen, the next screen allows selection of the discipline that is to be reviewed (Figure 13). For this demonstration, the discipline "Architectural" is chosen, which produces the menu shown in Figure 14.

Hypertext commands available at this stage of the program include the ability to print all checklists within the discipline, and access to additional information on the CSI Divisions used to classify the review guidelines. Both commands are displayed at the upper right hand corner of the screen. Selection of "PRINT ALL CHECKLISTS" displays a warning message (Figure 15), as this could produce over 30 printed pages of information. More information on the items contained in each of the CSI Divisions is available through the hypertext "CSI BROADSCOPE SECTIONS." Selecting this hypertext produces the menu shown in Figure 16, which in turn produces the applicable breakdown for each Division (as shown in Figure 17).

Because there are CSI Divisions common to each of the major review disciplines, a reference screen (Figure 18) appears before entering the divisions that exist in more than one discipline. This allows the reviewer to access the related information in other disciplines.

Proceeding with the program brings up the checklist of review guidelines on the screen (Figure 19). Each checklist has hypertext options that allow the user to: (1) export one or more comments from that screen (Figure 20), (2) print the entire checklist immediately, (3) view the related information in other disciplines, or (4) produce the text filename (Figure 21) for editing purposes. In most cases it is only necessary to press the space bar to continue viewing or to exit a checklist. If the "EXPORT COMMENTS" feature is used, however, it is necessary to enter a "0" (zero) (Figure 22) for the checklist number before pressing the space bar to indicate to the system that no more guidelines are being sent to the output file.

When the review session has been completed, selecting "End Constructibility Review" from any menu gives the user the option of printing out the information compiled in the output file. This is followed by a selection menu (Figure 23), which includes a warning to make sure the default printer is turned on. The final screen of the program presents point-of-contact information for users who have questions and comments on the system (Figure 24).

BCO ADVISOR				
The current directory is D:\ADVISOR				
Knowledge Base:				
<table border="1"> <tr> <td>Knowledge Base: ADVISOR</td> </tr> </table>				Knowledge Base: ADVISOR
Knowledge Base: ADVISOR				
F1 Help	F5 Evaluate	F7 Edit		
F2 Default Dir		F8 DOS	F10 Quit	

**Figure 5. Knowledge base selection.**

BCO ADVISOR				
USACERL				
BIDDABILITY, CONSTRUCTABILITY, OPERABILITY (BCO) ADVISOR				
<p>The USACE comprehensive design review program consist of five basic types of reviews: (1) Design, (2) Functional, (3) Value Engineering, (4) BCO, and (5) Technical. The BCO ADVISOR is an expert system designed to assist review managers perform BCO reviews. The aim of the system is to make available to reviewers the expertise necessary to carry out a thorough review of project drawings and documents. This in turn will help in the control of time and cost growth during the military construction process.</p> <p>Additional information is available for all highlighted items. Move the highlighted bar to the chosen topic by using the F3 key or your mouse, and select the item by using the F4 key or by clicking the left mouse button.</p>				
SCOPE OF WORK POINT OF CONTACT USER INTERFACE				
F1 Help	F3 Select	F5 Evaluate	F7 Edit	Pg 1 of 1
Space Cont.	F4 View	F6 Display KB	F8 DOS	F10 Quit

**Figure 6. Opening comments screen.**

BCO ADVISOR

USACERL  
BIDDABILITY, CONSTRUCTABILITY, OPERABILITY  
(BCO) ADVISOR

Biddability

Biddability is the degree to which the contract documents can be understood, administered, and enforced.

of five  
Engin  
expe

reviews. The aim of the system is to make available to reviewers the expertise necessary to carry out a thorough review of project drawings and documents. This in turn will help in the control of time and cost growth during the military construction process.

Additional information is available for all highlighted items. Move the highlighted bar to the chosen topic by using the F3 key or your mouse, and select the item by using the F4 key or by clicking the left mouse button.

SCOPE OF WORK  
POINT OF CONTACT  
USER INTERFACE

F1 Help

F5 Evaluate

F7 Edit

Pg 1 of 1

Space Cont.

F6 Display KB

F8 DOS

F10 Quit

**Figure 7. Hypertext demonstration for "biddability."**

BCO ADVISOR

Output from this review will be sent to a file called OUTPUT.FIL.  
If you would like the output to be stored in another file, please  
enter that filename now. => OUTPUT.FIL

F1 Help

F5 Evaluate

F7 Edit

F10 Quit

Space Cont.

F6 Display KB

F8 DOS

**Figure 8. Output file naming prompt.**

BCO ADVISOR

Output from this review will be sent to a file called OUTPUT.FIL.  
If you would like the output to be stored in another file, please  
enter that filename now. => OUTPUT.FIL

Help

Press F1 again for more help or SPACE  
to exit

There are three different ways you can  
provide information in a knowledge base

- 1) select from a pop-up menu
- 2) type a one line response
- 3) enter text in an editor window

To select the menu move the cursor using  
the cursor control keys or select the first  
letter of the answer than press <ENTER>

pg down

F1 Help
Space Cont.

Pg 1 of 3
F10 Quit

Figure 9. Help text.

BCO ADVISOR

Output from this review will be sent to a file called OUTPUT.FIL.  
If you would like the output to be stored in another file, please  
enter that filename now. => OUTPUT.FIL

This file already exists. Would you like to

Add Data to the File  
Overwrite the File  
Create a New File

F1 Help
F5 Evaluate
F7 Edit
F6 Display KB
F8 DOS
F10 Quit

Figure 10. Filing options.

BCO ADVISOR	
Output	Existing Project Data
If you	PROJECT NAME : Testing
enter t	LOCATION : USACERL
	DESCRIPTION : Test of referral system
This file	REVIEWER : John Doe COE
	REVIEW DATE : July 12, 1990
The above data exists for this review.	
Would you like to change anything?	
<div> <div>No</div> <div>Yes</div> </div>	
<div> <div>F1 Help</div> <div>F5 Evaluate</div> <div>F7 Edit</div> <div>F6 Display KB</div> <div>F8 DOS</div> <div>F10 Quit</div> </div>	

**Figure 11. Project data entry.**

BCO ADVISOR	
What type of review is being conducted?	
<div> <div>35% Concept Review</div> <div>95% Final Review</div> <div>Special Issues Review</div> <div>End Constructability Review</div> </div>	
<div> <div>F1 Help</div> <div>F3 Select</div> <div>F5 Evaluate</div> <div>F7 Edit</div> <div>F4 View</div> <div>F6 Display KB</div> <div>F8 DOS</div> <div>F10 Quit</div> </div>	

**Figure 12. Review selection.**



BCO ADVISOR —

95% FINAL REVIEW

What discipline would you like to review?

Architectural

Civil

Structural

Mechanical

Electrical

Operations/Maintenance

Environmental

Return to Opening Menu

End Constructability Review

F1 Help                      F5 Evaluate              F7 Edit

                                    F6 Display KB          F8 DOS              F10 Quit

**Figure 13. Discipline selection.**

BCO ADVISOR —

95% FINAL REVIEW: ARCHITECTURAL                      PRINT ALL CHECKLISTS

What CSI division would you like to review?                      CSI BROADSCOPE SELECTIONS

General Requirements

Sitework

Concrete

Masonry

Metals

Wood & Plastics

Thermal & Moisture Protection

Doors & Windows

Finishes

Specialties

Equipment

Furnishings

Conveying Systems

Return to Discipline Menu

End Constructability Review

F1 Help              F3 Select              F5 Evaluate              F7 Edit

                            F4 View              F6 Display KB              F8 DOS              F10 Quit

**Figure 14. Division selection.**

BCO ADVISOR							
95% FINAL REVIEW What CSI division would you like to review?	PRINT ALL CHECKLISTS CSI BROADSCOPE SELECTIONS						
<div style="border: 1px solid black; padding: 10px; margin: 0 auto; width: 80%;"> <p>Print All Checklists Within A Dicipline</p> <p>WARNING: Your Print buffer may not be large enough to contain all the text files within one whole discipline. Do you still wish to continue with this print routine?</p> <div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: 150px;">           No            Yes         </div> </div>							
<table style="width: 100%; border: none;"> <tr> <td style="border: none;">F1 Help</td> <td style="border: none;">F5 Evaluate</td> <td style="border: none;">F7 Edit</td> </tr> <tr> <td style="border: none;">F6 Display KB</td> <td style="border: none;">F8 DOS</td> <td style="border: none;">F10 Quit</td> </tr> </table>		F1 Help	F5 Evaluate	F7 Edit	F6 Display KB	F8 DOS	F10 Quit
F1 Help	F5 Evaluate	F7 Edit					
F6 Display KB	F8 DOS	F10 Quit					

**Figure 15. The print all checklists option.**

BCO ADVISOR									
Select a CSI Division to display the corresponding Broadscope Sections									
<div style="border: 1px solid black; padding: 10px; margin: 0 auto; width: 80%;"> <p>General Requirements</p> <p>Sitework</p> <p>Concrete</p> <p>Masonry</p> <p>Metals</p> <p>Wood &amp; Plastics</p> <p>Thermal &amp; Moisture Protection</p> <p>Doors &amp; Windows</p> <p>Finishes</p> <p>Specialties</p> <p>Equipment</p> <p>Furnishings</p> <p>Conveying Systems</p> </div>									
<table style="width: 100%; border: none;"> <tr> <td style="border: none;">F1 Help</td> <td style="border: none;">F3 Select</td> <td style="border: none;">F5 Evaluate</td> <td style="border: none;">F7 Edit</td> </tr> <tr> <td style="border: none;">F4 View</td> <td style="border: none;">F6 Display KB</td> <td style="border: none;">F8 DOS</td> <td style="border: none;">F10 Quit</td> </tr> </table>		F1 Help	F3 Select	F5 Evaluate	F7 Edit	F4 View	F6 Display KB	F8 DOS	F10 Quit
F1 Help	F3 Select	F5 Evaluate	F7 Edit						
F4 View	F6 Display KB	F8 DOS	F10 Quit						

**Figure 16. Broadscope selection screen.**

BCO ADVISOR											
CSI DIVISION 1 - GENERAL REQUIREMENTS											
01010 Summary of Work	01100 Special Projects Procedures										
01020 Allowances	01200 Project Meetings										
01025 Measurement and Payment	01300 Submittals										
01030 Alternates/Alternatives	01400 Quality Control										
01040 Coordination	01500 Construction Facilities and Temporary Controls										
01050 Field Engineering	01600 Material and Equipment										
01060 Regulatory Requirements	01650 Starting of System/Commissioning										
01070 Abbreviations and Symbols	01700 Contract Closeout										
01080 Identification Systems	01800 Maintenance										
01090 Reference Standards											
<table border="0"> <tr> <td>F1 Help</td> <td>F5 Evaluate</td> <td>F7 Edit</td> <td>Pg 1 of 1</td> </tr> <tr> <td></td> <td>F6 Display KB</td> <td>F8 DOS</td> <td>F10 Quit</td> </tr> </table>				F1 Help	F5 Evaluate	F7 Edit	Pg 1 of 1		F6 Display KB	F8 DOS	F10 Quit
F1 Help	F5 Evaluate	F7 Edit	Pg 1 of 1								
	F6 Display KB	F8 DOS	F10 Quit								

Figure 17. Broadscope breakdown.

BCO ADVISOR														
95% FINAL REVIEW: ARCHITECTURAL		PRINT ALL CHECKLISTS												
What CSI division would you like to review?		CSI BROADSCOPE SELECTIONS												
Reference														
You are in Final Review: Architectural: General Requirements.														
There is related information available in the following sections of the program. Select a hypertext topic if you would like to view it now, otherwise press SPACE to continue.														
CIVIL STRUCTURAL MECHANICAL ELECTRICAL														
<table border="0"> <tr> <td>F1 Help</td> <td>F3 Select</td> <td>F5 Evaluate</td> <td>F7 Edit</td> <td>Pg 1 of 1</td> </tr> <tr> <td></td> <td>F4 View</td> <td>F6 Display KB</td> <td>F8 DOS</td> <td>F10 Quit</td> </tr> </table>					F1 Help	F3 Select	F5 Evaluate	F7 Edit	Pg 1 of 1		F4 View	F6 Display KB	F8 DOS	F10 Quit
F1 Help	F3 Select	F5 Evaluate	F7 Edit	Pg 1 of 1										
	F4 View	F6 Display KB	F8 DOS	F10 Quit										

Figure 18. Discipline cross-referencing.

Review Guidelines				
ARCHITECTURAL: GENERAL REQUIREMENTS				
EXPORT COMMENTS	PRINT CHECKLIST	RELATED INFORMATION		
		TEXT FILENAME		
1. Indicate security requirements of employees.				
2. Show traffic control during construction.				
3. Insure that test methods, material specification or other manuals are consistent with civil or military designations as applicable.				
4. Coordinate large scale plans and elevations with small scale plans.				
5. Coordinate building sections and elevations.				
6. Show efficiency of fire-safety features and egress system as incorporated into the building layout.				
F1 Help	F3 Select	F5 Evaluate	F7 Edit	Pg 1 of 5
Space Cont.	F4 View	F6 Display KB	F8 DOS	F10 Quit

**Figure 19. Checklist of review guidelines.**

Review Guidelines				
ARCHITECTURAL: GENERAL REQUIREMENTS				
EXPORT COMMENTS	PRINT CHECKLIST	RELATED INFORMATION		
Checklist number for printing? => 4	TEXT FILENAME			
1. Indicate security requirements of employees.				
2. Show traffic control during construction.				
3. Insure that test methods, material specification or other manuals are consistent with civil or military designations as applicable.				
4. Coordinate large scale plans and elevations with small scale plans.				
5. Coordinate building sections and elevations.				
6. Show efficiency of fire-safety features and egress system as incorporated into the building layout.				
F1 Help	F3 Select	F5 Evaluate	F7 Edit	
Enter Accept	F4 View	F6 Display KB	F8 DOS	F10 Quit

**Figure 20. Exporting comments.**

Review Guidelines											
ARCHITECTURAL: DOORS AND WINDOWS											
EXPORT COMMENTS	PRINT CHECKLIST	TEXT FILENAME									
<ol style="list-style-type: none"> <li>1. Drawings should contain details of door head, jamb and threshold assemblies.</li> <li>2. Coordinate door schedule with floor plans.</li> <li>3. Show door grilles, specify proper finish, core type as required.</li> <li>4. Show protective angles at overhead door jambs.</li> <li>5. Coordinate <span style="border: 1px solid black; padding: 2px;">Text File Name</span></li> <li>6. Coordinate <span style="border: 1px solid black; padding: 2px;">The text file for this checklist is A950800.TXT</span> ct templates.</li> <li>7. Specify face veneer or stained doors.</li> <li>8. Coordinate doors from throat dimensions with wall framing and finishes.</li> </ol>											
<table style="width: 100%; border: none;"> <tr> <td style="width: 25%;">F1 Help</td> <td style="width: 25%;">F5 Evaluate</td> <td style="width: 25%;">F7 Edit</td> <td style="width: 25%;">Pg 1 of 1</td> </tr> <tr> <td>Space Cont.</td> <td>F6 Display KB</td> <td>F8 DOS</td> <td>F10 Quit</td> </tr> </table>				F1 Help	F5 Evaluate	F7 Edit	Pg 1 of 1	Space Cont.	F6 Display KB	F8 DOS	F10 Quit
F1 Help	F5 Evaluate	F7 Edit	Pg 1 of 1								
Space Cont.	F6 Display KB	F8 DOS	F10 Quit								

**Figure 21. Text file name screen.**

Review Guidelines															
ARCHITECTURAL: GENERAL REQUIREMENTS															
EXPORT COMMENTS	PRINT CHECKLIST	RELATED INFORMATION													
Checklist number for printing? => 2		TEXT FILENAME													
<ol style="list-style-type: none"> <li>1. Indicate security requirements of employees.</li> <li>2. Show traffic control during construction.</li> <li>3. Insure that test methods, material specification or other manuals are consistent with civil or military designations as applicable.</li> <li>4. Coordinate large scale plans and elevations with small scale plans.</li> <li>5. Coordinate building sections and elevations.</li> <li>6. Show efficiency of fire-safety features and egress systems as incorporated into the building layout.</li> </ol>															
<table style="width: 100%; border: none;"> <tr> <td style="width: 25%;">F1 Help</td> <td style="width: 25%;">F3 Select</td> <td style="width: 25%;">F5 Evaluate</td> <td style="width: 25%;">F7 Edit</td> </tr> <tr> <td>Enter Accept</td> <td>F4 View</td> <td>F6 Display KB</td> <td>F8 DOS</td> </tr> <tr> <td colspan="4" style="text-align: right;">F10 Quit</td> </tr> </table>				F1 Help	F3 Select	F5 Evaluate	F7 Edit	Enter Accept	F4 View	F6 Display KB	F8 DOS	F10 Quit			
F1 Help	F3 Select	F5 Evaluate	F7 Edit												
Enter Accept	F4 View	F6 Display KB	F8 DOS												
F10 Quit															

**Figure 22. Exiting the checklist function.**

BCO ADVISOR			
<p>Would you like a hard copy of the comments you sent to your output file?</p> <p>Please make sure that your default printer is on.</p> <div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: 150px;"> <p>No</p> <p>Yes</p> </div>			
F1 Help	F5 Evaluate	F7 Edit	
	F6 Display KB	F8 DOS	F10 Quit

**Figure 23. Printing an output file.**

BCO ADVISOR	
<p style="text-align: center;">USACERL BCO ADVISOR</p> <p style="text-align: center;">Questions or comments on the system may be addressed to: Simon Kim (X269) or Maria Tupas (X547) at: USACERL ATTN: FS/ P. O. Box 4005 Champaign, IL 61824-4005 800-USA-CERL</p> <p style="text-align: center;">Please press SPACE to exit.</p>	
Space Cont.	<p style="text-align: right;">Pg 1 of 1</p> <p style="text-align: right;">F10 Quit</p>

**Figure 24. Final reference screen (with point-of-contact information).**

## 6 INTERIM CONCLUSIONS AND CURRENT EFFORTS

Design review information can be collected and organized in a useful way. The procedure for doing this in the most efficient manner for the largest number of design reviewers has not yet been completed.

An interim concept BCO ADVISOR has been created, based on comments and suggestions made at a USACERL-hosted workshop in March 1990. The program will be sent to selected FOAs for evaluation and comment. Those comments will then be used to formalize the BCO ADVISOR concept design.

Information acquisition is continuing and review guidelines have been incorporated into the BCO ADVISOR even as the structure and operational characteristics are finalized.

The BCO ADVISOR is the next step in improving the design review process. ARMS addressed the management of the process; the BCO ADVISOR addresses performance of the design review. The relationship between these two systems is illustrated in Figure 25. Review comments collected in ARMS will be analyzed and used to generate review guidance that will be stored in the BCO ADVISOR. The integration of these two systems will provide the Corps with an effective design review system.

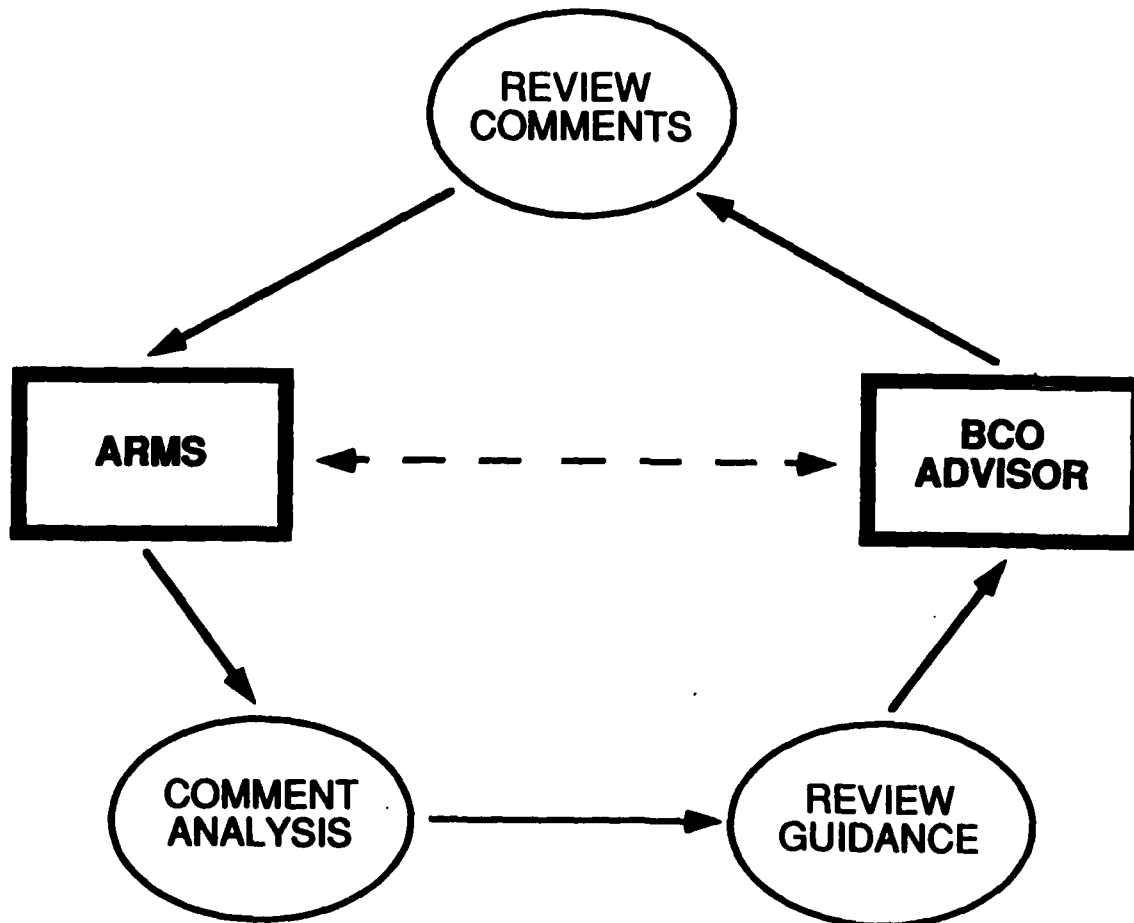


Figure 25. Improvement of design review.

## **APPENDIX A:**

### **DIVISION AND DISTRICT CHECKLISTS/MANUALS/GUIDES**

- U.S. Army Corps of Engineers, *Construction Biddability, Constructibility, Operability* ER 415-1-11 (Department of the Army, 1988).
- U.S. Army Corps of Engineers, *Engineering and Design: Design Analyses* ER 1110-345-700 (1982).
- U.S. Army Corps of Engineers, Buffalo District, *Engineering and Design: Biddability, Constructibility, and Operability Review Procedures* (1984).
- U.S. Army Corps of Engineers, Charleston District, *Design Checklist and Review Procedure Guide* DP 1110-1-1 (1987).
- U.S. Army Corps of Engineers, Fort Worth District, *Design Checklists* (1987).
- U.S. Army Corps of Engineers, Huntsville Division, *Design Review, Military Projects, Procedures and Feedback* (CE Training Management Division, 1989).
- U.S. Army Corps of Engineers, Huntsville Division, *Military Design Review and Feedback Principles and Procedures* (CE Training Management Division, 1987).
- U.S. Army Corps of Engineers, Jacksonville District, *Estimates Section Check List* (1988).
- U.S. Army Corps of Engineers, Little Rock District, *Quality Design Checklists* (1988).
- U.S. Army Corps of Engineers, Los Angeles District, *Operating Procedure Memorandum: Review of Civil Works Plans and Specifications* (1988).
- U.S. Army Corps of Engineers, Missouri River Division, *Architectural Review Checklists* (1988).
- U.S. Army Corps of Engineers, Mobile District, *Design Check Lists For Use By Arch.-Engrs. and Gov't. Personnel* (Design Branch Engineering Division, 1975).
- U.S. Army Corps of Engineers, Mobile District, *Design Manual for A/E Services* DP 1110-1-1 (Design Branch Engineering Division, 1986).
- U.S. Army Corps of Engineers, New Orleans District, *Constructibility Checklist* (1988).
- U.S. Army Corps of Engineers, Norfolk District, *Design Review Guide* (1988).
- U.S. Army Corps of Engineers, Pacific Ocean Division, *Design Check Lists* (1986).
- U.S. Army Corps of Engineers, Philadelphia District, *Biddability, Constructibility, Operability Checklist* (1988).
- U.S. Army Corps of Engineers, Sacramento District, *A-E Quality Control Checklist* (1985).
- U.S. Army Corps of Engineers, Seattle District, *Check List for Design Document Review: Madigan Army Medical Center* (1988).
- U.S. Army Corps of Engineers, Seattle District, *Design Guide for Architects-Engineers* (1983).
- U.S. Army Corps of Engineers, Vicksburg District, *Checklist Review of Plans and Specifications: Locks and Dams* (1988).



## **APPENDIX B:**

### **INDUSTRY AND ACADEMIC SOURCES**

Finley, Lloyd S., *Examination of the Constructibility Review in Government Contracting* (1984).

Hancher, Donn E., and James D. Lutz, *Final Report: Proposed Framework for the Development of a Design Quality Review Database* (1988).

Lozar, Charles C., *Final Report on Results of Technical Review of Constructibility Comments from Selected Projects* (1984).

O'Connor, J.T., S.E. Rusch, and M.J. Schulz, *Constructibility Improvement During Engineering Procurement* (1986).

Tatum, C.B., J.A. Vanegas, J.M. Williams, *Constructibility Improvement During Conceptual Planning* (1986).

Thomas H. Randolph, *Current Practices Related to Constructibility Reviews in the Public and Private Commercial Construction Industry* (1984).

Winsper, Loretta E., *Design Constructibility Reviews* (1987).

## **APPENDIX C:**

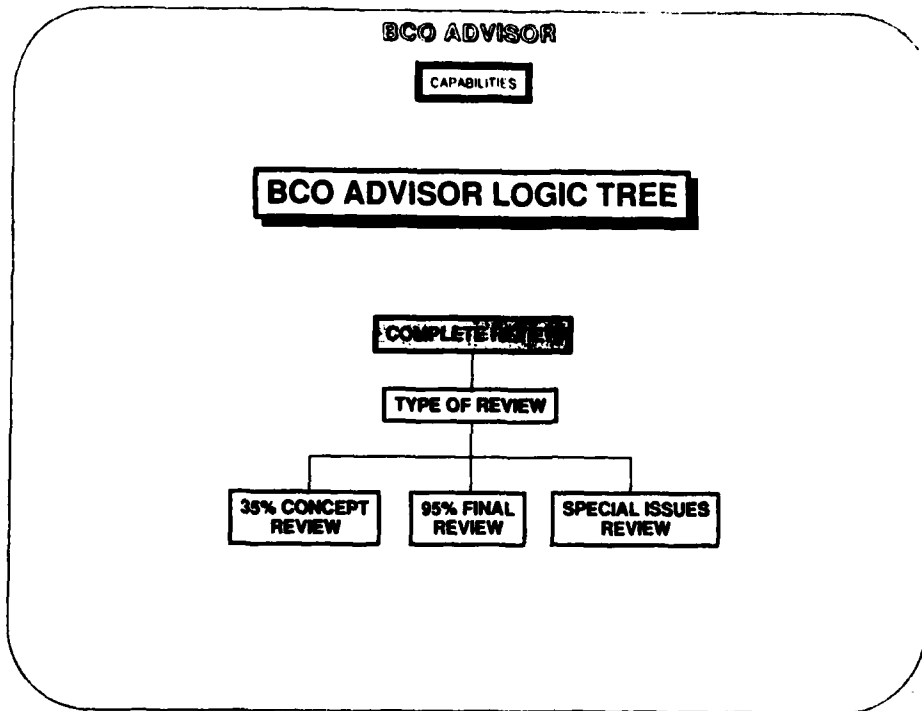
### **REDICHECK SYSTEM SAMPLE CHECKLIST**

#### **3. Plan Check Civil**

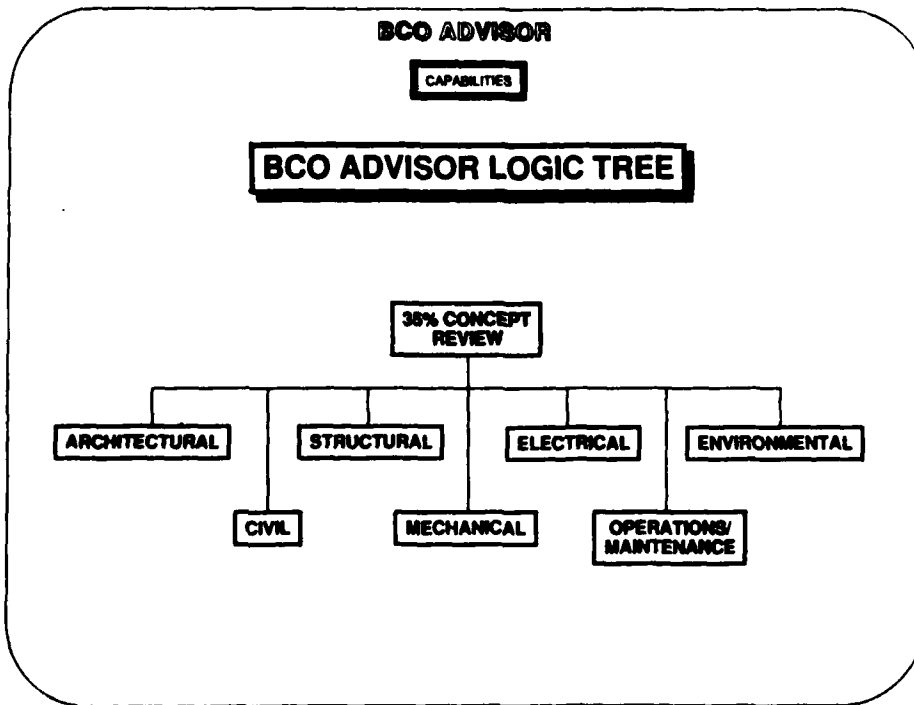
- a. Verify that site plans with new underground utilities (power, telephone, water, sewer, gas, storm drainage, fuel lines, grease traps, fuel tanks) have been checked for interference.
- b. Verify that existing power/telephone poles, pole guys, street signs, drainage inlets, valve boxes, manhole castings, etc. do not interfere with new driveways, sidewalks, or other site improvements.
- c. Verify that limits of clearing, grading, sodding, grass or mulch are shown.
- d. Verify fire hydrants and street light poles are shown in their intended locations.
- e. Verify profile sheets show other underground utilities and avoid conflicts.
- f. Verify horizontal distances between drainage structures and manholes match with respect to scaled dimensions and stated dimensions on both plans and profile sheets.
- g. Verify provisions have been included for adjusting valve box and manhole castings (sewer, power, telephone, drainage) to match final or finish grade of pavement, swales, or sidewalks.
- h. Verify all existing and proposed grades are shown.

**APPENDIX D:**

**BASIC BCO ADVISOR LOGIC TREES**



**Figure D1. Overall review tree.**



**Figure D2. 35 Percent Concept Review Tree.**

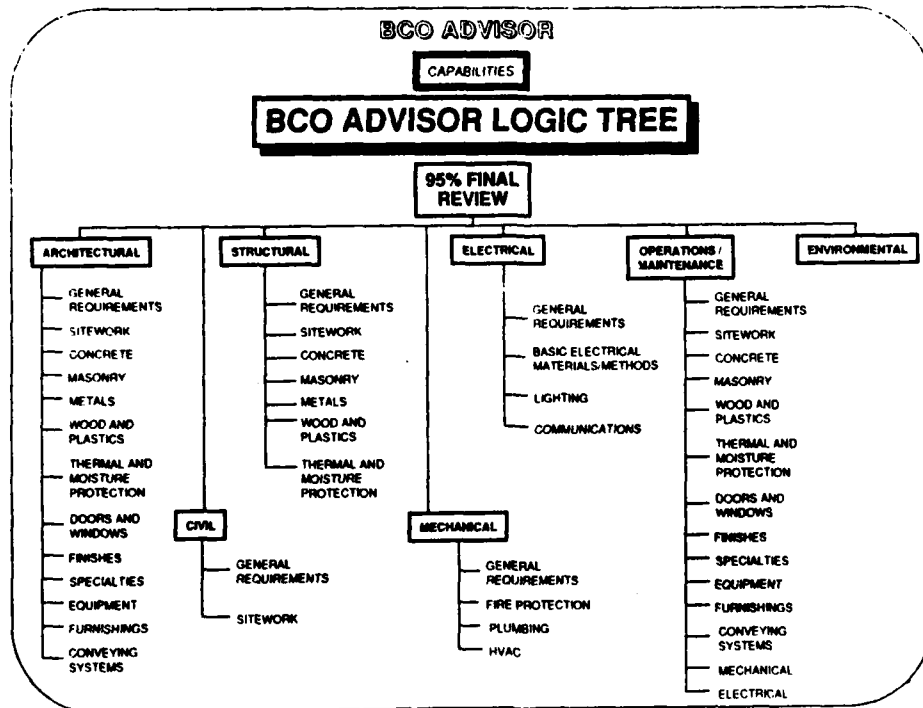


Figure D3. 95 Percent Final Review Tree.

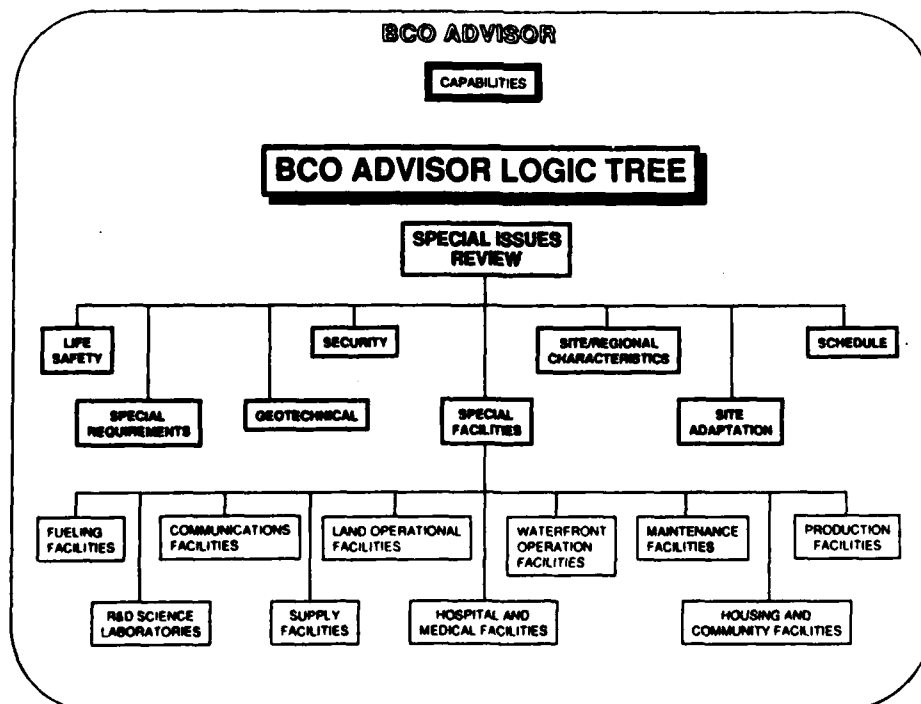


Figure D4. Special Issues Review Tree.

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ATTN: CEHEC-IM-LP (2)  
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ATTN: CECW-O  
ATTN: CECW-P  
ATTN: CECW-RR  
ATTN: CEMP  
ATTN: CEMP-C  
ATTN: CEMP-CE  
ATTN: CEMP-E  
ATTN: CERD  
ATTN: CERD-C  
ATTN: CERD-M  
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